A. Cover Sheet *(Attach to front of proposal.)*

1. Specify: ☒ agricultural project or ☐ urban project ☐ individual application or ☒ joint application

2. Proposal title—concise but descriptive: Evaluation of Salt-Tolerant Floral and Forage Crops As A Strategy For Conserving Fresh Water Resources

3. Principal applicant—organization or affiliation: USDA/Agricultural Research Service George E. Brown, Jr., Salinity Laboratory

4. Contact—name, title: James A. Poss, Soil Scientist

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9. Funds requested—dollar amount: $ 69,900

10. Applicant cost share funds pledged—dollar amount: $

11. Duration—(month/year to month/year): 06/15/01 to 06/15/03

12. State Assembly and Senate districts and Congressional district(s) where the project is to be conducted: 64th State Assembly, 36th State Senate, 43rd Congressional

13. Location and geographic boundaries of the project: USDA/ARS George E. Brown, Jr., Salinity Laboratory, Riverside, California located on the campus of the University of California, Riverside.

14. Name and signature of official representing applicant. By signing below, the applicant declares the following:
    - X the truthfulness of all representations in the proposal;
    - X the individual signing the form is authorized to submit the application on behalf of the applicant;
    - X the applicant will comply with contract terms and conditions identified in Section 11 of this PSP.

Michael C. Shannon, Associate Area Director
(printed name of applicant)

FEB 13 2001
(date)

Michael C Shannon
(signature of applicant)

Evaluation of Salt-tolerant Floral and Forage Crops As a Strategy For Conserving Fresh Water Resources

Personnel:

PIs			
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B. Scope of Work

Relevance and Importance

1. Executive Summary

Saline irrigation water resources, primarily drainage effluents, but also including some groundwaters in subregions 14 through 21 of the SFP, will be important components to meeting the Water Use Efficiency (WUE) Program goals to conserve and recycle water throughout the State. Quantifiable Objectives, including increasing water supplies for beneficial uses through reductions in nonproductive Evapotranspiration (ET), can benefit from a study that evaluates the response of a number of promising salt-tolerant forage and floral crops to salinity levels typical of those present in the San Joaquin Valley. Experiments will be conducted at the USDA/ARS George E. Brown, Jr., Salinity Laboratory in Riverside, CA using greenhouse and outdoor sand tank lysimeter systems. These sand tank systems have been used successfully to evaluate a number of field crops (forages, cereals, several leafy vegetables, *Lesquerella*, and halophytes) and trees (i.e., poplar, mesquite, eucalyptus, pistachio) with precise control of soil water salinity. Screening trials of promising forage (*Medicago*, *Trifolium*, *Cynodon*, and *Paspalum* cultivars) and floral crops (*Limonium*, *Chrysanthemum*, *Protea* cultivars) as suitable alternatives will be conducted. Both forage and floral crops will be evaluated when grown with saline water that may range from 4 to 30 dS m^{-1}, as appropriate. Maximum allowable salinities for production of marketable products will be determined. Strategies that maintain or enhance product quality including temporary salt stress

release/imposition according to morphological stage of plant development will be tested for floral crops. Forages will be scored based on biomass production, mineral concentrations, forage quality, and water use efficiency, whereas floral rankings will emphasize floral quality, size, color, and quantity of blooms.

The research project will involve four USDA Agricultural Research Service scientists joined by two University of California scientists from the Davis campus. The project team has combined expertise in the areas of soil physics and irrigation management, plant physiology, plant nutrient-salinity interactions, plant genetics, and floriculture.

2. Water issues and consistency with water management plans.

Competition between water users for high-quality water has increased as the population has increased (Shannon and Grieve, 2000). Substantial volumes of saline drainage water, used either exclusively or in conjunction with strategic minimal fresh water supplements, can successfully be substituted in systems where good quality water is currently used extensively for irrigation.

The use of saline waters to produce plants can be beneficial in two ways. First, information on crop productivity under saline conditions is important in sequential drainage reuse systems designed to reduce volumes of saline drainage waters that pose environmental hazards (Grattan et al., 1999; San Joaquin Valley Drainage and Implementation Program, 2000. Through identification of salt-tolerant forage and floral plants considered viable economic alternatives to salt sensitive species or cultivars, fresh water supplies could be conserved while maintaining economic productivity of agricultural and horticultural operations. These systems can benefit from identification of appropriate crops that could grow well and maintain reduction of drainage water volumes under saline ($EC_e = 10$ dS m^{-1}) to extremely saline ($EC_e >$ 25 dS m^{-1}) conditions by maintaining substantial rates of transpiration (EC_e is the electrical conductivity of the soil saturation extract – an indicator of soil salinity). A second benefit of using saline water for irrigation may be conservation of good quality water supplies otherwise consumed for all other beneficial uses at the local, regional, Bay-Delta, State or federal level. Through the substitution of saline waters for production of crops suited to these conditions, fresh water supplies are conserved through matching of water quality with plant productivity.

Furthermore, plant water use efficiency has been shown to increase with increasing salinity. Eucalyptus trees irrigated with simulated San Joaquin drainage water had up to a 3-fold increase in long-term transpiration efficiency (Poss, et al., 2000). Although plant productivity is proportional to ET, the optimization of this relationship is important and potentially can contribute to meeting ET reduction targets.

Forage grasses and legumes will use more water than most tree species in the same locations, and provide feed for livestock. The forages can be substituted for trees in existing agro-forestry models where drainage water volume reduction is desired. Warm season grasses like *Cynodon* and *Paspalum* species tolerate high temperatures and salinity and grow in the spring and summer (Oster et al., 1999a).

Usually, salt-tolerant plants are less economically attractive than traditionally grown salt-sensitive crops. However, some floral crops are extremely salt tolerant (Dr. Ed. Glenn, University of Arizona, personal communication) and may provide growers with more economical and environmentally acceptable options where saline drainage or well waters are available.

3. Nature, scope, and objectives.

The need for strategies that address drainage water reuse through development of new management concepts is more important in saline soils because of the importance of balancing salts and water use. Quantitative information that relates water quality and water use is limited, but essential to the understanding of these processes at various scales. Although crop-water quality production functions have been estimated for some agronomic crops (Letey and Dinar, 1986), information is currently not available for many alternative crops. The scope of the work is potentially quite broad given the potential number of permutations of specific soil salinities and plant species. Generally, quantitative evaluations will be useful for local planning in a wide range of locations and conditions.

The objective of the study is to evaluate a number of potential forage and floral crops in terms of production potential when irrigated with saline drainage water. In addition, screening and selection of these candidate species adapted to high salinities would aid future efforts to reuse drainage waters

4. Technical/Scientific Merit, Feasibility, Monitoring, and Assessment

Our hypothesis is that water use efficiency on a regional basis, through reduction of transpiration and conservation of fresh water supplies, will be increased with the use of saline water for irrigation Warm season forages (Table 1) and flower species (Table 2) will be evaluated for water use and productivity under simulated saline conditions in an experimental facility at the USDA/ARS laboratory in Riverside, CA. The water use efficiency of the non-saline control will be compared with that of the saline treatment. The concept here is to produce plant material as feed or for ornamental purposes while requiring little or no good quality water. One added benefit is that salt-affected areas could improve productivity while reducing drainage water volumes and conserving high quality water. Since forages are usually vegetative material, flowering and fruit development are not important growth stages for these crops. Forages, being perennial also provide partial to full ground cover during the growing season, thus reducing the evaporation component and decreasing the non-productive water use component. In addition, forages are usually grown over several years without reseeding such that seedling establishment problems are minimized.

Floral crops, however, have critical growth stages where salinity induction or relief may have profound effects on productivity. Ornamental products can be produced with limited or no requirements for good water quality if salt-tolerant germplasm is used. Some information exists on the salt-tolerance of some floral species, but little or no information is available on water use under saline conditions.

The experiments will be conducted in greenhouse and outdoor sand tanks located at the USDA/ARS George E. Brown, Jr., Salinity Laboratory in Riverside, California. The outdorr sand tanks act as drainage lysimeters allowing for a water balance of the system and control of soil water salinity uniformly throughout the rootzone. A large set of 24 tanks (1.5 m x 3 m x 2 m deep) and a small set of 24 tanks (0.8 m x 2.0 m x 0.8 m deep) both filled with washed sand having an average bulk density of 1.45 Mg m^{-3} comprise the outdoor facilties. Each tank is irrigated with a solution contained in individual reservoirs having a volume of approximately 4000 L. The salt solutions will be prepared to simulate San Joaquin Valley drainage waters based on predictions of speciation model simulations (Suarez and Simunek, 1997). These solutions would contain a full complement of nutrients equivalent to a half-strength Hoagland's solution. The solutions are applied through surface irrigation and collected into subsurface drains in a closed system loop from reservoir to soil then back to the reservoir. Irrigation volumes and frequencies would be maintained to achieve a leaching fraction near unity to avoid salt buildup. Total ET would be measured for each tank after maximum drainage every 72 hours via an automated refill-water metered system connected to a data-logging computer. The greenhouse system is similar on a smaller scale. A Class I agrometerological station is installed immediately adjacent to the outdoor facility. Micrometerological data including sand and air temperature, pan evaporation, PAR, RH, and wind velocity will be recorded.

5. Schedule of Proposed Project.

Task/ Deliverable Item		Projected Cost
Forage Experiments Planning Meetings Data Collection		$27,000
Floral Experiments Planning Meetings Data Collection		$28,300
Data Analysis/ Consultant Anal./ Meetings		$10,200
Manuscript/ Report Preparation		$2,300

Technology/ Information Transfer									$2,100
Quarterly Expenditure Projection	$15K	$10K	$5K	$5.3K	$15K	$10K	$5K	$4.6K	Total $69,900
Schedule Date:	6/15	9/01	12/01	3/02	6/15	9/02	12/02	3/03	6/03

6. Monitoring and Assessment

Dry matter production rates of the forages and the water balance of the sand tanks will be measured periodically. Electrical conductivities (EC) will be monitored as will pH to document actual salinity and pH of the irrigation solutions. The forage tissue will be dried, ground, and analyzed for major inorganic salts (Na, Ca, Mg, K, Cl, P, S,) and forage quality. There may some added benefit of using drainage water with trace minerals such as boron and selenium as these are necessary nutrients for animals and in previous studies have not accumulated to potentially toxic levels (Grattan et al., 1999). Furthermore, floral crops may allow for greater accumulation of such trace elements than forages where concentrations need to be suitable for animal consumption.

Water use efficiency will be calculated based upon accumulated biomass or economic product for each salinity treatment. Experimental designs would consist of randomized block with several salinity targets for forages and similar studies for floral crops. Additional salinity stress/stress relief experiments will be conducted for flower crops in a greenhouse sand-tank facility to quantify the number of suitable flowers that could be salable. Floral crops will be assessed based on commercially acceptable criteria for flowers and biomass production will also be measured as an indicator of plant performance under the range of saline treatments.

Our results could be passed on to related demonstration projects located near the west side of the San Joaquin Valley so that more salt tolerant material could be used as the soil is degraded by long term use of drainage water as an irrigation water source.

C. Outreach, Community Involvement, and Information Transfer.

1. Outreach efforts.

Both the University of California Cooperative Extension and USDA's Agricultural Research Service consider outreach activities a high priority. Through extension workshops and meetings with groups such as the UC Management and Reuse of Agricultural Workgroup and the California Nurseryman's Association. Information obtained from these studies will be communicated to the end user. The UC Management and Reuse of Agricultural Workgroup consisting of individuals from the University of California, DWR, USDA, CSUF, USBR, RCD's, and several irrigation and drainage districts on the Westside of the San Joaquin Valley Exchange of research findings and information through this group will be critical.

Opportunities for community involvement range from student employment to cooperation with specific private and public entities. The USDA/ARS maintains a Research Information Management System that contains a technology transfer database (TEKTRANS) on the internet that includes title summaries describing the research project and findings.

Investigators will publish results in a number of outlets including newsletters, popular articles and trade magazines such as Irrigation Journal and the California Nurseryman. Additional information transfer will be provided through publication of results in pertinent popular circulars and scientific peer-reviewed journals.

All users of fresh water supplies could potentially benefit from the use of saline water for irrigation in production agriculture. It is conceivable that tribal interests and the interests of people in disadvantaged communities could be well served through water policy options previously not considered for conserving water resources.

D. Qualifications of the Applicants, Cooperators, and Establishment of Partnerships

The research project will involve four USDA Agricultural Research Service scientists who have been involved in investigations of plant salt tolerance in laboratory and field settings over two decades. They are joined by a University of California Extension Plant Water Relations Specialist and a Professor in the Department of Environmental Horticulture. Both are located at the Davis campus. The project team has combined expertise in the areas of soils and irrigation management, plant physiology, plant nutrient-salinity interactions, and floriculture management issues. Resumes are attached.

Role of Investigators

Poss: Project development, assembling scientific team. Will assist in development of experimental methods, set-up, and harvests. Will assist in the analysis of data and presentation of reports.

Grieve: Assist in selection of forage and floral crops to be evaluated in experiments. Will coordinate collection of physiological data. Will play major role in preparation of reports and manuscripts.

Shouse: Salt and water balance analysis. Will assist in harvest and selection of sampling criteria and monitoring irrigation procedures.

Zeng: Screening and selection of salt tolerant plants for further evaluation.

Grattan: Assist in development of proposal. Will assist in synthetic drainage water compositions and aspects of the soil-water-plant continuum. Assisting in technical information transfer.

Leith: Assist in development of proposal. Development of floral quality evaluation criteria. Assisting in technical information transfer.

External cooperators will include pest management consultants and forage quality assessment consultants to maintain plant health and determine forage quality parameters. Communication with the cut flower representatives will be important to meet industry standards

E. Costs and Benefits.

1. Budget Summary and Breakdown.

Title: Evaluation of Salt-tolerant Floral and Forage Crops As a Strategy For Conserving Fresh Water Resources

Primary Investigator/Scientific Team: J.A. Poss, C.M. Grieve, P. J. Shouse, S.R. Grattan, J. H.Lieth, and L. Zeng.

	Year One (2001 –2002)	Year Two (2002-2003)
Salaries and Wages	20,000	21,000
Fringe Benefits	2,200	2,300
Supplies	3300	2000
Equipment	1500	1500
Services or Consultants	3500	2700
Travel	4100	4100
Other Direct Costs	700	1000
Total	35, 300	34,600

2. Budget Justification: Labor costs for undergraduate/graduate student assistance and benefits. Equipment and supplies include salts and nutrients for sand culture systems, plant

materials, and maintenance costs associated with monitoring meters for conductivity, pH, and local weather conditions, soil moisture, etc. Consulting fees for pest control and analytical services for some plant analysis. Travel includes trips to and from Riverside/Davis including overnight costs.

3. Project outcomes and benefits are not easily quantifiable since many factors can vary the final analysis. Qualitative outcomes and benefits would hopefully be dominated by the conservation of fresh water resources that would benefit all users of good quality water. Additional benefits to industry may include lower production costs and additional flexibility in product development. Utilization of saline waters can accelerate needed isolation and screening of mutant or salt resistant germplasm. For example, Rodriguez-Perez et al. (2000) recently observed surviving *Protea* plants essentially undamaged alongside plants that died as a result of salinity indicating genetic diversity with respect to salinity stress. These survivors could be selected to establish salt tolerant cultivars for forage and floral industry through selection techniques. Other benefits at the production level might include positive features of moderately salt-stressed plants such as increase in the number of flowers or more desirable growth habit or both. If saline waters of poor quality containing nitrate salts are used, then reductions in nitrate potential to leach to groundwater would also occur. Drainage waters on the Westside of the San Joaquin Valley are notoriously high in nitrate and reuse of drainage water would reduce the nitrate level in the final effluent (SJVDIP, 2000). Economic assessments would be assisted with such a database to infer cost parameters for economic model predictions.

References

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Table 1. List of potential forage species for salt tolerance screening.

Family, Genus, Species	Putative Salt Tolerance (EC_i in dS/m)	Notes	References
Leguminosae			
Trifolium Alexandrinum L.	>6	Moderately yielding, good quality forage	Poss (1984) Kaddah (1962)
Berseem Clover		Two cut ecotype not evaluated Under salinity stress	Dan Putnam, UC Agronomist for Alfalfa and Forage Crops Personal communication
Medicago sativa			
CUF alfalfa	*>8*	Little information on salt tolerance	Dan Putnam, UC Agronomist for Alfalfa and Forage Crops Personal communication
Gramineae			
Paspalum spp.			
Duncan *Polo*	>8	Sand cultures	Shannon et al., (1998)
Cynodon spp.			
Tifton 85 Bermuda	*>8*	Sand Cultures	Shannon et al., (1998)

Table 2. List of potential floral species for salt tolerance screening.

Family, Genus, Species	Putative Salt Tolerance (EC_i in dS/m)	Notes	References
Asteraceae			
Aster 'Monte Casino'	>4.2; SYD n.d.	Hydroponic cultures	Sonneveld et al. (2000)
Chrysanthemum morifolium	>8	Yield and quality greater at 8 dS/m compared to controls	Rahi and Datta (2000) Prabucki et al. (1999)
Caryophyllaceae			
Dianthus caryophyllus Carnation 'Adefie'	4.3; SYD 3.9%	Hydroponic cultures	Sonneveld et al. (2000)
Plumbaginaceae			
Limonium auriculae-ursifolium	43		Aronson, (1989)
Limonium carolinanium	47		Taylor (1939)
Limonium californicum	Sea water	Physiological measurements	Woodell and Mooney (1970)
Limonium perezii	Sea water; 56 dS/m		Aronson, (1989)
Limonium sinuatum	Sea water; 56 dS/m		Aronson, (1989)
Proteaceae			
Protea obtusifolia	∃4.2	Individuals resistant to 8.2 dS/m	Rodriguez-Perez et al. (2000)

SYD = Significant Yield Decrease
*Yield decrease per unit increase in salinity.